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mal body by the channel of the sense organs and the sensory nerves. Reaching a ganglion it is received by the cells, perhaps by many of them through the division of the fiber into its constituent fibrillæ. It either continues over its original fibrillæ to the motor nerves which issue from these cells, or is transferred, partly or wholly, to other fibrillæ by induction. In such a case it may be carried to other motor nerves, or enter upon a short local circuit and yield the local effect called memory; that is, a peculiar organizing effect in which is represented its peculiar character. Or this secondary circuit may convey it to a higher or more central ganglion, in which the same modes of distribution may be exercised. In highly developed animals it may pass through several such intermediate ganglia, and be finally, in part or wholly, transferred by induction to the cerebral ganglion. In this it exerts but one action, that whose effects we call memory, a permanent transformation produced in some organizable substance. This effect is the germ of all mental development.

(To be continued.)

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AFFINITIES OF ANNELIDS TO VERTEBRATES.

BY E. A. ANDREWS.

AS a group the annelids exhibit in a prominent degree both bilateral symmetry and segmentation. The former is well expressed in the adult, in the early larval stages and even at the period of closure of the blastopore, when the radial symmetry of the gastrula becomes replaced by bilateral symmetry.

Segmentation, so pronounced in the adult, is not found in what we may regard as the most primitive larval form, the Trochophora of such forms as *Serpula*, or as more perfectly expressed in some species of *Polygordius*.

These two fundamental characters, bilateral symmetry and segmentation, naturally lead to a comparison of this group with the other segmented Bilateralia, of which the Vertebrata especially have attracted attention in seeking for the allies of the annelids; or rather in the attempt to derive the vertebrates from invertebrate groups, the annelids have furnished important aid.

Of those who have paid especial attention to the subject and who maintain a close relationship between the annelids and vertebrates, may be mentioned Semper, Dohrn and Hatschek. Semper seems to have advanced the most evidence in support of his

views, working mainly from the standpoint of comparative anatomy, and drawing little or no material from the larval stages of annelids. His views may be briefly (and thus necessarily imperfectly) stated as follows: Regarding the distinction of ventral and dorsal surfaces as of little morphological importance, we may make a direct comparison of annelid and vertebrate by supposing the mouth of the annelid to be a new formation, and that a mouth once existed upon the hæmal (dorsal) side of the annelid which was homologous with the mouth of the vertebrate (Figs. 1, 2).

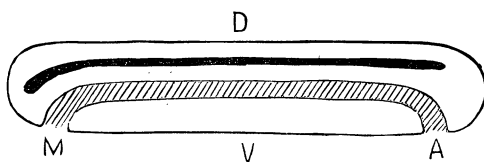


FIG. 1.—Diagram of a vertebrate according to Semper's view, showing relative positions of nerve-cord, digestive tract, mouth (*M*) and anus (*A*); *D*, dorsal, *V*, ventral surface.

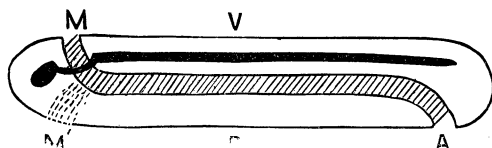


FIG. 2.—Diagram of an annelid according to Semper. *M*, mouth; *A*, anus; *M'*, primitive mouth; *D*, dorsal, *V*, ventral surface.

He draws close comparison between the muscles, nervous structures and excretory organs of the two groups, basing his views largely upon the study of the urogenital organs in the lower vertebrates and the process of asexual reproduction in certain oligochaetous annelids.

In these forms new individuals are formed in chains by the appearance of budding zones across the body of the asexual parent, each of which zones gives rise anteriorly to the trunk of one zoïd, and posteriorly to the head of the next following zoïd, so that two adjacent zones form a new individual between them, and parts of the new individual in front of the anterior zone and behind the posterior zone. As these individuals eventually break loose as forms like the parent it is necessary that each acquire a new mouth and œsophagus, supra-œsophageal ganglion and muscles. In the formation of these structures from the preëxisting tissue and from more indifferent embryonic cells,

Semper finds an identity in fundamental plan between annelid and vertebrate. Though establishing so many homologies between the two groups, he does not derive one from the other, but inclines to the view that both are descendants of a segmented planarian-like ancestral form which on the one hand gave rise to the vertebrate group by the enlargement of its anterior ganglion to form a brain and by the union of its separate nerve cords along the dorsal side to form the spinal cord, while on the other hand the annelid was formed by the acquirement of a new mouth piercing the nerve cord or passing between the still separate nerve cords and by the closure of the primitive mouth.

Dohrn's views on the affinities of the annelids to the vertebrates are very interesting, if perhaps of less importance as being purely hypothetical.

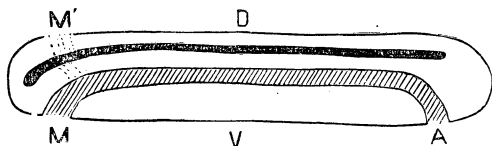


FIG. 3.—Diagram of vertebrate according to Dohrn. *M*, mouth; *A*, anus; *M'*, primitive mouth; *D*, dorsal, *V*, ventral surface.

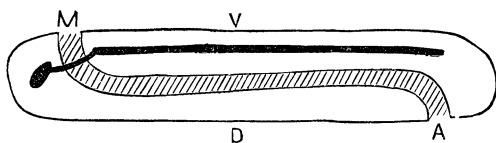


FIG. 4.—Diagram of an annelid according to Dohrn. *M*, mouth; *A*, anus; *D*, dorsal, *V*, ventral surface.

Homologizing the dorsal surface of one group with the ventral of the other, he finds the necessity of supposing a new mouth to have existed in one group, and unlike Semper regards the vertebrate as the form in which this new structure was formed (Figs. 3, 4). Seeking a trace of the primitive mouth of the vertebrate homologous with the mouth of the annelid, which is on the neural side, he finally concluded that the *fossa rhomboidalis* of the vertebrate represented the area of the nervous system formerly pierced by the oesophagus on its way to a neural mouth, there being thus a circum-oesophageal ring formed homologous with that of the annelid. The present mouth of the vertebrate was thus a new formation having no homologue among the annelids.

The genetic relationship of the two groups he conceives to have been that of diverging branches from a common ancestor. This hypothetical ancestral form was a segmented annelid-like creature with a chorda, gills on all the segments, supported by a cartilaginous rod on the side of each segment, with a neural mouth like that of an annelid and with a pair of segmental organs in each segment opening to the exterior and also internally into the digestive tract. From this ancestor the vertebrates arise by an interesting series of modifications in structure due to "change of function" of the primitive structures; some of the segmental organs gave rise to the mouth and branchial clefts, while others formed the genital and urinary ducts and even the anus; the branchiæ were variously modified to form the branchiæ of the vertebrate, its fins and limbs and perhaps the external genital organs; the cartilaginous supporting rods gave rise to the ribs, skeleton of the limbs and part of the skull.

This hypothetical ancestor was more highly specialized than the present annelids, which have since degenerated, perhaps (he thinks), owing to the sharp competition between the more annelid-like and the more vertebrate-like forms of the common ancestral group. The whole tenor of Dohrn's work inclines to the conclusion that annelids, like ascidians, etc., are degenerate vertebrates.

However satisfactory in explaining an origin of the vertebrates from an hypothetical ancestor this hypothesis may or may not be, it apparently is unsatisfactory in so far as it concerns the annelids.

Much of the evidence in support of Hatschek's views is derived from a consideration of the development of annelids, both of Polychætæ and of Oligochætæ.

His comparison of the two groups, annelids and vertebrates, is essentially that of Dohrn's (Figs. 3, 4) except that he does not place the point where the primitive œsophagus pierced the nervous system at the *fossa rhomboidalis* but at the *hypophysis cerebri*, a position more comparable to the present position of the mouth among the annelids, as it is farther forward, in the unsegmented portion of the head. He reduces the excretory organs in both groups to a common type represented by a transient stage in the larva of certain annelids when the branched excretory tube in the head of a Trochophora larva sends back a branch into the trunk, this longitudinal tube gives rise to the segmental tube in each

segment of the trunk, and thus a stage is present where the segmental organs are connected by a common longitudinal duct. In the annelid this connection is lost (though perhaps retained in a few), while each segmental organ acquires an external opening. In the vertebrate the primitive connection persists, and no external opening is developed for each segmental organ.

The conclusion reached by Hatschek is that annelids and vertebrates have had a common segmented ancestor, which did not differ much from such a simple annelid as *Polygordius*.

The three authorities now mentioned represent sufficiently the views of those finding more or less close relationship between the vertebrates and the annelids; there are others who regard this relationship as very remote, if existing at all, either placing other invertebrate forms nearer the vertebrates or separating this group from the annelids, from consideration simply of the fundamental differences of the two groups. Among the latter may be reckoned Mr. Adam Sedgwick, whose ingenious hypothesis includes the question of the relationship of these two groups, though advanced with the much wider object of accounting for segmentation and the origin of the Triploblastica from coelenterate-like forms. Founded upon the behavior of the blastopore and upon the structure of the coelenterates, the hypothesis calls for a coelenterate-like ancestor with mouth and anus part of one common opening to the digestive tract which bore diverticula on each side, indicating a segmentation, and communicating with each other as well as with the exterior; the nervous system formed a broad ring around the mouth-anus (Fig. 5). From this common hypothetical ancestor the annelids were derived by the separation of the mouth and anus, by the partial fusion of the two sides of the nerve-ring along the median line between the mouth and the anus, with atrophy of the part behind the latter opening

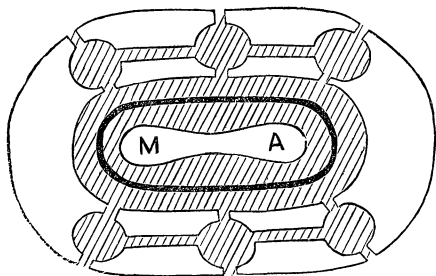


FIG. 5.—Diagram of Sedgwick's hypothetical ancestral form of vertebrates and annelids, showing mouth (*M*) and anus (*A*) as part of one common opening; digestive tract and pouches and nerve-ring.

and by loss of the connections of the lateral pouches with one another and with the digestive tract, thus forming the segmented body-cavity and the segmental organs. The vertebrate was formed by a more complete union of the lateral parts of the nerve-ring between the separated mouth and anus, together with disappearance of its two ends, by the persistence of some anterior pouches to form branchial clefts, by the loss of external openings for others which remained connected with one another and with the digestive tract at one point to form part of the body-cavity and the urogenital ducts, and finally by the retention of only the outer openings of the last pair of pouches which form part of the body-cavity and the abdominal pores. Mouth and anus are thus homologous in the two groups, and primitively neural in position; the mouth in the vertebrate acquired its present ventral or hæmal position by advancing around the anterior end of the body.

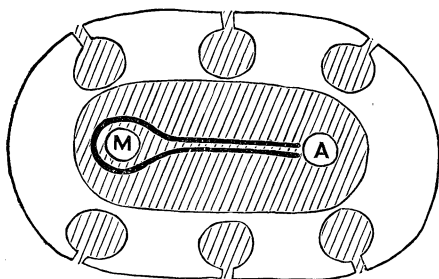


Fig. 6.

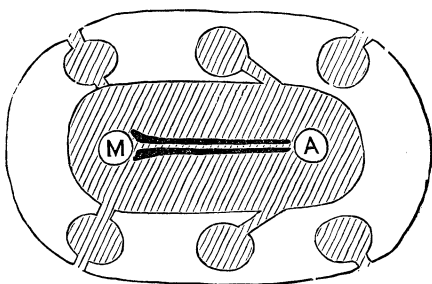


Fig. 7.

FIG. 6.—Diagram of an annelid according to Sedgwick. *M*, mouth; *A*, anus.
FIG. 7.—Diagram of a vertebrate according to Sedgwick. *M*, mouth; *A*, anus, with spinal cord between.

A still more remote separation of the annelids from the vertebrates is required by the comparisons instituted by Goette from a study chiefly of the development of planarians and annelids; the fundamental ground-plan of the two groups is, he thinks, essentially different, as shown by the entirely diverse ways in which the gastrula is modified in the two to form the adult. In the annelid the blastopore closes along a line which corresponds to the longitudinal axis of the adult, the mouth being formed from its anterior part and the anus near its posterior end; the nervous cord is formed along this line of union of the lips of the blastopore. Thus the ventral surface of the adult represents the

blastopore area of the gastrula—the area opposite the upper end (summit) of the gastrula and in a plane at right angles to the chief axis of the gastrula, and along this ventral surface or blastopore area the nerve-cord is developed. In the vertebrate, on the contrary, the blastopore closes in a small area representing the posterior end of the adult and entirely behind the nervous system, corresponding in part to the anus in position. The blastopore area being thus the hind end of the adult, the ventral surface of the adult is formed from one side of the gastrula while the nerve-cord develops upon the opposite *side* of the gastrula in a position more nearly parallel with the chief axis of the gastrula.

In an annelid, then, the ventral surface with the nerve-cord correspond to the original lower or blastopore surface of the gastrula, and the mouth represents the anterior end of the blastopore. In a vertebrate the ventral surface corresponds to a side of the gastrula, while the surface homologous to the annelid's ventral surface is found represented in the vertebrate merely by the anal region, this being the blastopore area of the gastrula; the mouth in the vertebrate is a new structure formed remote from the area of the blastopore, and not at all comparable to the annelid mouth except in function.

Figs. 8 and 9, copied from Goette's work, will serve to illustrate this comparison of the two groups.

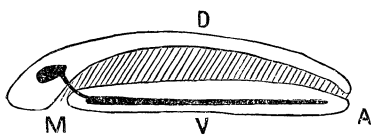


Fig. 8.

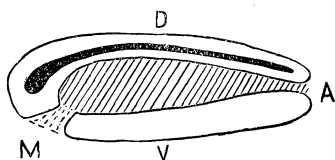


Fig. 9.

FIG. 8.—Diagram of annelid according to Goette. *D*, dorsal, *V*, ventral surface; *M*, mouth; *A*, anus. FIG. 9.—Diagram of vertebrate according to Goette. *D*, dorsal, *V*, ventral surface; *M*, mouth; *A*, anus.

The preceding statements may serve to indicate the chief views upon the subject, showing how much difference prevails in the hypotheses advanced to solve the important morphological problem of the exact affinities of the annelids and vertebrates, and at the same time indicating, perhaps, a tendency among those who have recently investigated the embryology of the annelids to

separate this group much farther from the vertebrates than was customary when most of the evidence was derived from the comparative anatomy of the adults.

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THE USE OF COPPER BY THE DELAWARE INDIANS.

BY CHARLES C. ABBOTT, M.D.

IN the *American Antiquarian* of November, 1884, Mr. Edwin A. Barber, speaking of the Indians of Pennsylvania, remarks:

"The copper age is represented by a few specimens of copper implements which have been discovered in different localities; but these could scarcely have been produced by the Lenni Lenape tribe. They were doubtless obtained from the ancient miners of Lake Superior, or at least were the remains of the industry of the mound-building race, which had found their way into Pennsylvania."

Referring in 1881 to the use of copper, by the New Jersey tribes, I also expressed the opinion that it was "not improbable that all the copper articles found along the Atlantic coast, were brought from western localities."¹ A careful re-survey of many localities where ordinary Indian stone implements occur in abundance; and correspondence with collectors in various portions of New Jersey and Eastern Pennsylvania now convince me that the use of copper, as implements and ornaments, was much more common than I supposed, and that among our Delaware Indians were many coppersmiths.

In the fifteenth annual report of the Peabody Museum of American Archæology, Professor Putnam describes two examples of copper spears, of which he says, while "these spear-heads closely resemble one in the State Historical Society of Wisconsin," yet they differ in the important feature of having smooth edges, while the Wisconsin specimen has a serrated point. These were both made "from a mass of native copper, hammered into shape, as shown by several small laminations which can be distinctly traced."

From the same locality a third example has been found (Fig. 1)

¹ Primitive Industry, p. 413. Salem, Mass., 1881. Geo. A. Bates.